Eskom	Standard	Technology

Title: **MULTI-FUNCTION SECONDARY PLANT TEST SET STANDARD**

Unique Identifier:	**240-170000773**
Alternative Reference Number:	**n/a**
Area of Applicability:	**Engineering**
Documentation Type:	**Standard**
Revision:	**1**
Total Pages:	**41**
Next Review Date:	**April 2027**
Disclosure Classification:	**Controlled Disclosure**

Compiled by	Approved by	Authorized by
Kashveer Jagdaw	Ian Worthington	Nelson Luthuli
Senior Engineer: PTM&C Protection Technology & Support	Chief Engineer: Grid Operations	Senior Manager (Acting): PTM&C
Date: 13/04/2022	Date: 13/04/2022	Date: 13 April 2022

Supported by SCOT/SC

Anita Oommen

SCOT Protection and Automation SC

Date: 13 April 2022

PCM Reference: **240-44509543 – PCM Design Systems**

SCOT Study Committee Number/Name: **WG63 – Test set specification**

Content

1. Introduction

The multi-function secondary test set standard is developed to enable the establishment of a contract for the procurement of multi-function tests sets, software modules and accessories as required by the Secondary Plant fraternity, for testing protection and metering and schemes. In addition, this specification will also cater for IEC 61850 testing, monitoring and analysing tools used during commissioning and maintenance.

2. Supporting Clauses

2.1 Scope

The document defines minimum specifications for multi-function test sets, software modules and upgrades as well as test set accessories for testing protection and metering schemes. The document also details the requirements for IEC 61850 testing tools.

2.1.1 Purpose

The document shall be used when procuring multi-function test sets with appropriate automated test templates for relevant schemes, software modules and test set accessories. This shall preferably be in the form of a contract which would lend itself to volume discounts and standardise the test sets in use by all Secondary Plant personnel for a defined period.

2.1.2 Applicability

This document shall apply to the Secondary Plant environment throughout Eskom Holdings Limited Transmission Division.

2.2 Normative/Informative References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] 240-76624513: Standard for the calibration of test instruments used by field staff

[2] 240-77224537: Standard for calibration and limits of errors for single- and three phase energy meters

[3] 240-95637584: Work instruction for control of monitoring and measuring equipment

[4] 240-55410927: Cyber security standard for operational technology

[5] BS EN/IEC 61000-4-15: Testing and measurement techniques — Flickermeter — Functional and design specifications

[6] SANS/IEC 62052-11: Electricity metering equipment (A.C) – General requirements, tests and test conditions Part 11: Metering equipment

[7] IEC 62053-22: Electricity metering equipment – Particular requirements – Part 22: Static meters for AC active energy (classes 0.1S, 0.2S and 0.5S)

[8] SANS/IEC 62053-24: Electricity metering equipment – Particular requirements – Part 24: Static meters for fundamental component reactive energy (classes 0.5S, 1S, 1, 2 and 3)

[9] SANS 474: Electrical metering – Standard requirements

[10] BS EN/IEC 62586-1: Power quality measurement in power supply systems, Part 1: Power quality instruments (PQI)

[11] BS EN/IEC 62586-1: Power quality measurement in power supply systems, Part 1: Power quality instruments (PQI)

[12] IEC 61588: Precision clock synchronisation protocol for networked measurement and control systems

[13] IEC 61850-5: Communication networks and systems for power utility automation; Part 5: Communications requirements for functions and device modules

[14] IEC 61850-7-1: Communication networks and systems for power utility automation; Part 7-1: Basic communication structure – Principles and models

[15] IEC 61850-7-2: Communication networks and systems for power utility automation; Part 7-2: Basic information and communication structure – Abstract communication service interface (ACSI)

[16] IEC 61850-7-3: Communication networks and systems for power utility automation; Part 7-3: Basic communication structure – Common data classes

[17] IEC 61850-7-4: Communication networks and systems for power utility automation; Part 7-4: Basic communication structure – Compatible logical node classes and data object classes

[18] IEC 61850-7-410: Communication networks and systems for power utility automation; Part 7-410: Hydroelectric power plants – Communication for monitoring and control

[19] IEC 61850-7-420: Communication networks and systems for power utility automation; Part 7-420: Basic communication structure – Distributed energy resources logical nodes

[20] IEC 61850-8-1: Communication networks and systems for power utility automation; Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3

[21] IEC 61850-9-2: Communication networks and systems for power utility automation; Part 9-2: Specific communication service mapping (SCSM) – Sampled Values over ISO/IEC 8802-3

[22] UCA GUIDELINE IEC 61850-9-2LE: Implementation guideline for digital interface to instrument transformers using IEC 61850-9-2

[23] IEC 61869-9: Instrument transformers – Part 9: Digital Interface for Instrument Transformers (Incorporates the 9-2LE Guide and is due for publication in 2016)

[24] IEC 61850-9-3: Communication networks and systems for power utility automation; Part 9-3: Precision time protocol profile for power utility automation

[25] IEEE C37.238-2011: IEEE Standard Profile for Use of 1588™ Precision Time Protocol in Power System Applications

[26] NRS 048-2: Voltage characteristics, compatibility levels, limits and assessment methods

[27] SANS 164-0: Plug and socket-outlet systems for household and similar purposes for use in South Africa (Includes all normative references as applicable referenced within SANS 164-0)

[28] SANS 603201: Appliance couplers for household and similar

[29] SANS/IEC 60950-1: Information technology equipment – Safety; Part 1: General requirements

[30] SANS/IEC 61000-3-2: EMC Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)

[31] SANS/IEC 61000-4-2: EMC Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test

[32] SANS/IEC 61000-4-3: EMC Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test

[33] SANS/IEC 61000-4-4: EMC Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test

[34] SANS/IEC 61000-4-5: EMC Part 4-5: Testing and measurement techniques – Surge immunity test

[35] SANS/IEC 61000-4-6: EMC Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields

[36] SANS/IEC 61000-4-07: EMC Part 4-07: Testing and measurement techniques – General guide on harmonics and inter-harmonics measurements and instrumentation, for power supply systems and equipment connected thereto

[37] SANS/IEC 61000-4-11: EMC Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variation immunity tests

[38] SANS/IEC 61000-4-30: EMC Part 4-30: Testing and measurement techniques – Power quality measurement methods

[39] SANS/IEC 61000-6-4: EMC Part 6-2: Generic standards – Immunity for industrial environments

[40] SANS/IEC 61000-6-4: EMC Part 6-4: Generic standards – Emission standard for industrial environments

[41] SANS/IEC 61010-1: Safety requirements for electrical equipment for measurement, control, and laboratory use; Part 1: General requirements

[42] SANS/IEC 61326: Electrical equipment for measurement, control and laboratory use — EMC requirements

[43] SANS/IEC 61326-1: Electrical equipment for measurement, control and laboratory use – EMC requirements

[44] Low Voltage: Directive 2006/95/EC

[45] EMC: Directive 2004/108/EC - electromagnetic compatibility

These documents are indispensable for the application of this document, i.e., documents to be used together with this document.

2.2.2 Informative

[46] IEC 61850 Sampled Values – Technology Promise, Open Issues, and the State of International Standardization (Cigre Study Committee B5 Colloquium, August 25-31. 2013 Belo Horizontale, Brazil

2.3 Definitions

2.3.1 General

Definition	Description
Analogue input	This is a hardwired input and supports current and voltage inputs which typically are DC and have a positive – zero – negative range.
Binary input	This is a hardwired input and shall support both a dry or wetted voltage (typically up to 220Vdc) type input. This shall be configurable via the test set operating software/interface.
Binary output	This is a controllable contact output that is used to control certain aspects of the test object. The contacts shall have a practical specification allowing switching of at least 220Vdc with a realistic current switching capability.
Calibration	Set of operations that establish, under specified conditions, the relationship between the values indicated by a measuring system and the corresponding values of a quantity realized by a reference standard or a working standard
Ethernet port	This is typically a copper based RJ45 female Ethernet port which allows connection to process equipment including PC's, routers, switches and IED's to allow for full control of the test set and testing of IED's typically supporting IEC61850. The connector should also provide options for two or more RJ45 and fibre optic Ethernet ports.

Definition	Description
Multi-function Secondary test set	This is an instrument that has current and voltage outputs which may provide single to multi-phase current and voltage outputs which are controllable in terms of magnitude, phase angle and frequency, binary inputs and outputs, analogue inputs and may include Ethernet and USB ports for connecting to a controlling computer using the Microsoft Windows operating system. The Ethernet ports shall also support testing of devices compliant with IEC61850. The multi-function test set is controlled using the vendor supplied software and/or hardware interface and may include other features useful in testing of Secondary Plant IED's.
Reference standard	Meter used to measure the unit of electrical energy and power. It is designed and operated to obtain the highest accuracy and stability in a controlled laboratory environment
USB port	This is a port typically used to connect a controlling PC to the test set to allow full control of the test set properties.
Working standard	Meter used to measure the unit of electrical energy and power, for use in meter test units. The working standard is calibrated against the reference standard

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
AC	Alternating current
BI	Binary input
BO	Binary output
DC	Direct current
EMC	Electromagnetic compatibility
GOOSE	Generic Object Oriented Substation Events
GPS	Global Positioning System
IEC	International Electrotechnical Commission
IED	Intelligent electronic device
mA	Milli ampere
MFT	Multi-function secondary plant test set
mm	Milli-metre
PC	Windows based computer (Desktop or Laptop)
PTP	Precision time protocol (IEC61588; IEC61850-9-3 and IEEE1588)
SANAS	South African National Accreditation System
SELV	Safety Extra Low Voltage
UCA	Utility Communication Architecture
USB	Universal serial bus
V	Voltage (Usually Vac or Vdc, denotes alternating or direct current voltage)

2.5 Roles and Responsibilities

The standard will be utilised by relevant departments for the procurement of test sets required for testing Protection and Metering schemes.

2.6 Process for Monitoring

The PTM&C Protection Technology and Support Department shall ensure that a national contract is in place for the necessary products, upgrades, spares, repair, and calibration of equipment.

2.7 Related/Supporting Documents

Not applicable.

3. Test Set Hardware Specification

The test set hardware specification is defined here. All specifications detailed herein are deemed the minimum acceptable requirement.

3.1 Multi-function test set casing and carry handle

a) The casing shall be metallic or reinforced plastic or a combination of both. The casing shall be durable and provide protection to the innards from ingress of dust, debris and mechanical forces imparted to the unit during transport and normal usage in a substation environment.

b) The test set shall have a sturdy carrying handle with a comfortable nonslip grip. The handle is to be adjustable when placed on a floor or desk to facilitate easy connection to the input and outputs.

c) All test inputs/outputs shall be placed in a logical layout on the front/top (hereafter termed “front”) plate of the device. Some outputs may be on the back of the unit. The rear panel is not an absolute requirement but should be separate to the usual test input and output terminals, typically the rear panel houses communication ports, 230 Vac power supply input plug and specialised outputs / inputs such as GPS, low level input / output or synchronising plugs (synchronising of test set current and voltage channels). The MFT shall make available any other safety earth connection on the rear of the unit as determined necessary by the test set manufacturer and standards body. The Ethernet and USB ports shall preferably be located on the rear of the device.

d) The test set ON/OFF switch shall preferably be located on the front panel and shall be illuminated when ON. The ON/OFF switch shall be readily accessible by the MFT operator.

e) The casing shall at minimum be protected by a sturdy carrying bag with pockets to contain the power supply lead, Ethernet/USB cables and test leads. The bag shall have a carrying sling with non-slip shoulder pads that allow for easy and safe transport of the test set by one person. The casing shall have sturdy replaceable protective feet on all deemed standing sides, typically the bottom and back side. The casing vents shall be on the non-exposed sides to minimise the possibility of debris or liquid ingress. Thus, in the normal working position the test set should be the least vulnerable to dust and spillage.

3.2 Front panel connections

The front panel connections shall be seen to be the following as a minimum:

a) Voltage outputs

b) Current outputs

c) Binary inputs

d) Binary outputs

e) Auxiliary power supply

f) Analogue inputs

3.2.1 Voltage outputs

a) The terminal physical attributes shall be as described under terminals.

b) The voltage outputs shall be in various configurations as per the test set offering.

c) Thus, a single-phase test set, or module may have only one output designated live and neutral.

d) A three-phase test set shall at minimum have three phases and a neutral, which shall be clearly indicated on each phase/neutral. A three-phase test set shall have at least an additional and separately controlled output with a live and a neutral.

e) An advanced model of the MFT shall have additional multiple three phase configurable voltage outputs for testing of newer generation schemes.

f) It is expected that a MFT voltage channel can be controlled in terms of voltage amplitude, phase shift and frequency. The test set voltage outputs shall be capable of supplying DC voltage at the specified AC rating.

g) The voltage outputs shall have short circuit and overload protection. These conditions to be flagged by the test set control and/or the PC software package, the flagging method should be such that the flag will not go unnoticed by the MFT operator. The voltage outputs shall have protection against inadvertent application of external voltage. The level of protection shall be technically quantified by each *Supplier* at tender stage.

h) The voltage outputs shall be clearly marked with the phase's red in colour and the neutral black. When supplying DC voltage, the polarity will be designated such that red coloured terminal shall be the positive terminal and the black coloured terminal the negative terminal. The voltage output group shall have a visual indication (LED or similar) when energised.

i) The minimum output capability of the test set is detailed in section 4.0 in terms of rating and accuracy for all the variable components (Amplitude, phase angle and frequency)

3.2.2 Current Outputs

a) The terminal physical attributes shall be as described under terminals.

b) Current output configurations shall again be dictated by the MFT offerings. A single-phase test set, or module may only have one live and neutral output. A "three" phase test set shall have at least one set of terminals with three phases and one neutral.

c) An advanced model of the MFT shall have additional multiple three phase configurable current outputs for testing of newer generation schemes.

d) It is expected that a MFT current channel can be controlled in terms of current amplitude, phase shift and frequency

e) The current outputs shall have short circuit and overload protection. These conditions to be flagged by the test set control and/or the PC software package, the flagging method should be such that the flag will not go unnoticed by the test set operator. The current outputs shall have protection against inadvertent application of external voltage. The level of protection shall be technically quantified by each *Supplier* at tender stage.

f) The mentioned inputs and outputs shall preferably all be arranged on the front panel. However, some may be placed elsewhere on the test set should the available front panel space be an issue.

g) The minimum output capability of the test set is detailed in section 4 in terms of rating and accuracy for all the variable components (Amplitude, phase angle and frequency). The test set current outputs shall be capable of supplying DC current at the specified AC rating.

3.2.3 Synchronising of MFT current and voltage channels across test sets

Synchronising current and voltage channels of test sets with the following three possibilities:

1) Slaving together of test sets via electrical connection or Ethernet.

2) Via an external GPS unit, this would allow two or more tests sets to be synchronised either locally or geographically separated (between two substations or distributed control cubicles)

3) Via Ethernet based PTP locally at a substation or geographically displaced.

The basic requirement is GPS synchronisation (item 2) with items 1 and 3 being a distinct advantage.

The advanced model shall have items 1, 2, and 3.

3.2.4 Low level voltage outputs

The advanced test set shall have low level outputs for the testing of non-conventional IED's that accept inputs from other voltage sensors for example a Rogowski coil, thus the test set shall have the required resolution and accuracy when testing at this low voltage. These outputs may also be used to drive other accessories.

3.2.5 Binary inputs

a) The terminal physical attributes shall be as described under terminals.

b) The binary inputs shall be clearly marked and where polarity sensitive be marked with distinctive colours. Paired binaries shall be clearly indicated on the front panel.

c) The maximum input voltage shall be clearly indicated on the front panel. The preference is that all binary inputs are high impedance inputs.

d) The binary inputs may have additional functions such as counters, AC and DC measurement/recording capability. Additional software packages may be procured to activate these functions on the basic test set (hardware dependant). These functions shall be available as default on the advanced model.

3.2.6 Binary Outputs

a) The terminal physical attributes shall be as described under terminals.

b) Each output and output group are to be clearly marked in terms of function and output terminals to preferably be marked black or a colour agreed with by *The Purchaser*.

c) The maximum AC and DC voltage and current capability of each output shall be clearly marked on the front panel. 220 Vac is possibly the most onerous application.

3.2.7 Analogue DC Inputs

a) The terminal physical attributes shall be as described under terminals.

b) The Analogue DC inputs will be ±20mA and ±10V. The inputs would typically be for transducer testing and/or process feedback.

c) The inputs shall be protected from inadvertent over voltage or current to the level specified by the manufacturer.

d) The input terminals shall be clearly marked in terms of function and input quantity.

3.2.8 Auxiliary power supply output

The test set shall have an auxiliary DC output controllable from 0 to 250 Vdc. This power supply shall be able to power up typical test object as specified under hardware. The output shall have a visual indication (LED or similar) when energised. The output shall be short circuit and overload protected. The positive and negative terminals shall be clearly indicated.

3.2.9 Input and output terminals

a) The input/output terminals shall be suitable to accommodate the standard Banana plug connector with a plug diameter of 4mm nominal and a length of 20mm. These plugs are an international standard and widely used in the electrical test industry. The input/outputs shall be female and of a solid construction. An inadvertent accidental tug by errant personnel should not damage the receptacle. The receptacle shall be insulated from the casing at 1000 Vac. Any dangerous voltage present on the front panel outputs should indicate such by a lit indicator clearly associated with the grouped output or output. All these terminals shall have the same physical and electrical properties irrespective of function. The terminal shall be a blind terminal not allowing any object including dust to enter the test set via the female terminal.

b) Each output and output group are to be clearly marked in terms of function and also where polarity is important this is to be clearly marked. The preferred colour code for analogue outputs will be positive (+) = RED and negative (-) = BLACK.

c) For AC outputs typical descriptors such as L1, L2, L3, N / 1, 2, 3, N / A, B, C, N (to be configurable in software) shall be preferred. The phases shall all be the same colour and neutral shall be black. An exception with *The Purchaser* approval is possible.

d) Where connectors/receptacles are commonly connected internally this shall be clearly indicated on the front plate. All inputs shall clearly indicate the maximum voltage input allowed.

e) The connector receptacle design shall be such that inadvertent contact with the live part of the plug is not possible by the test set operator using bare hands. The terminals shall preferably be flush with the casing.

3.3 Rear panel

a) The rear panel of the test set should house the power supply receptacle, the Ethernet ports, a USB connector if made available and additional input/outputs as required. The input power supply level shall be clearly marked and separated from other inputs and outputs. The test set design may deviate from this requirement if the deviation is not impractical.

b) Any assisted cooling devices to be located at the rear panel. It shall be noted in the event of an operator error whereby the operator causes a catastrophic failure of the test set; the test set design should ensure that any gases generated are expelled at the rear of the device and away from the operator. The front panel usually facing the operator may not allow the ejection of any gas or material towards the operator.

c) The sides of the test set shall be free from any connectors, inputs, and outputs. This is to allow mounting in a rack.

3.4 Power Supply

a) The power supply to the test set shall be a single phase 230Vac, 50Hz supply rated at 15 A maximum. The Test set shall have a suitable on/off switch preferably mounted on the front panel (easily accessible by the test set operator in the event of a unsafe situation arising), the switch shall clearly indicate that it is either ON or OFF. The power supply lead shall plug into a standard South African 3 pin socket outlet and be separable from the test set via a suitable plug. This lead and plug arrangement shall include an integral earth wire. The power supply lead shall be at least 2 meter in length. The lead and insulation shall be flexible and rugged and not easily damaged. An added safety requirement is that the test set checks the integrity of the integral earth lead of the test set supply. The test set shall signal the absence of such an earth lead and indicate that the application of an external earth lead is required. The signal shall be via the controlling software and/or any other control interface offered.

b) The power supply receptacle shall preferably be located on the rear of the test set.

c) All aspects of the power supply, plugs and leads shall meet the relative SANS specification.

3.5 Ethernet ports

a) The preference is to utilise RJ45 copper Ethernet ports.

b) The test set shall have two RJ45 Ethernet ports, this is to allow synchronising of multiple test sets, conduct an IEC61850 session and control the test set.

c) Ethernet ports shall have the following functionality:

1) Test set control by PC/Controller and vendor software over Ethernet.

2) Time synchronisation over PTP.

3) Testing of IEC61850 based systems using both GOOSE and Sampled Values.

d) The basic model shall have items 1 and 2, with item 3 being activated by a module/software which can be added on by The Purchaser.

e) The Ethernet copper ports should be capable of supporting 10/100BASE-T or better, especially where the test set generates IEC61850 derived sampled values, here 10/1000BASE-T will be preferred, the 1Gbit capability shall be seen as essential for the advanced model with sampled value capability. For copper Ethernet the standard “RJ45” 8P8C female connector should be supplied. This connector should be an easily replaceable module, and it should be resistant to damage by personnel inadvertently tugging on the Ethernet cable plugged into the female Ethernet port located on the test set, thus the point of damage should be the RJ45 plug on the Ethernet cable.

f) Power over Ethernet is an essential requirement, this would be used to power up PTP time synchronisation-based units and other Ethernet based accessories requiring a power supply.

g) Lead lengths for copper Ethernet connection cable would be as per test set model specification in section 4.

h) An option with fibre optic Ethernet would be advantageous and typically support all common standards. Typically, multi-mode fibre capability would suffice. All popular connectors shall be supported.

3.5.1 Test set control by computer

Only Ethernet and / or USB communication shall be acceptable.

3.6 Cyber Security

Indication to be given as to the deemed test set vulnerability to cyber-attacks, and any preventative measures which are in place. Preference is for the test set to be secured from cyber-attacks to minimise the MFT as the entry point for any malicious attacks.

4. Detailed technical and software specification

The specification list details the minimum requirement for each specification type. This specification shall be the minimum acceptance criteria.

4.1 Power Supply

a)	Nominal Voltage	230 VAC
b)	Permissible Voltage Range	85 V - 265 VAC

c)	Nominal Frequency	50 Hz / 60 Hz
d)	Permissible Frequency Range	45 Hz - 65 Hz
e)	Power Consumption	Max 3450VA at 230VAC
f)	Rated Current	15A at 230VAC
g)	Connection	Standard AC sockets: Connector (SANS 60320-1, C13) and Inlet (SANS 60320-1, C14) Other SANS approved connectors and inlets may be considered.

4.2 Dimensions and Weight of the Test Set

a)	Volume	max. 45 litre
b)	Weight	max. 20 kg

4.3 Environment

a)	Operating Temperature	0 °C - 50 °C
b)	Storage Temperature	-25 °C - 70 °C
c)	Humidity	5 % - 95 % RH, non-condensing

4.4 Certificates

a)	Vibration	IEC60068-2-6
b)	Shock	IEC60068-2-27
c)	CE Mark	Yes or equivalent.
d)	EMC	The product adheres to the electromagnetic compatibility (EMC) Directive 2004 / 108 / EC (CE conform)
e)	EMC - Emissions	IEC 61326 Class A; IEC61000-6-4; SANS 61000-3-2/3; FCC Subpart B of Part 15 Class A
f)	EMC - Immunity	IEC 61326; IEC61000-6-2; IEC61000-4-2/3/4/5/6/11
g)	Safety	The product adheres to the low voltage Directive 2006 / 95 / EC (CE conform). IEC61010-1: Safety requirements for electrical equipment for measurement, control, and laboratory use; Insulation of PC and SELV Interfaces complies with SANS 60950-1 (Also EN)

h)	Independent Test Laboratory	Copies of test certificates from independent test laboratories proving compliance with the above standards are to be supplied together with the tender

4.5 Hardware

4.5.1 General

a)	All functions should be combined in one hardware unit
b)	The unit shall be of a robust and sturdy construction
c)	PC card design: Wire jumpers on a single printed circuit board are not permissible
d)	Electronic components: No potentiometers are allowed
e)	No moving elements or elements that are susceptible to damage, i.e. controls elements or displays on the face plate are permissible

4.5.2 Output Amplifiers

a)	The amplifier stages are to be fully electronic, i.e., not via transformer
b)	All current amplifiers to be fully protected against any open-circuit-, overload-, overburden- and over-temperature- condition. Any such condition is to be immediately displayed in all active software modules or test set specific controller. Except for an over-temperature condition an automatic shutdown of the amplifiers is not permissible. The withstand capability of the outputs when inadvertently connected to an external supply to be defined.
c)	All voltage amplifiers to be fully protected and immune against any short-circuit-, overload-, overburden- and over-temperature- condition. Any such condition is to be immediately displayed in all active software modules or test set specific controller. Except for an over-temperature condition an automatic shutdown of the amplifiers is not permissible
d)	All amplifiers to use linear amplification elements and to be dc-coupled. The neutrals of the voltage and current amplifiers shall be galvanically isolated (up to 2kV) from the ground/chassis of the test set. This is for the safety of the test set operating personnel and will ensure that the test set casing does not inadvertently subject the operator to any electrical shock.
e)	Ability to generate DC and AC signals
f)	The amplifiers, low-level outputs, the measurement inputs and the main power supply to be galvanically isolated from each other and earth (2kV insulation voltage)

4.5.3 Voltage Amplifiers

a)	Setting range	4x 0 - 300V_{rms} (L-N), 3x 0 - 520V_{rms} (L-L)
b)	Single phase operation	1x 0 - 600V_{rms} (L-L)
c)	Output power	3x 100VA at 100 - 300V (L-N) or
d)		1x 200VA at 100 - 300V (L-N) or
e)		1x 275VA at 200 - 600V (L-L)
f)	Minimum load current	3x 1A_{rms}; 1x 2A_{rms}
g)	Accuracy	error < 0.05% of reading (0 - 300V) + 0.02% of range
h)	THD+N	< 0.015%
i)	Phase error	<0.02°
j)	Connection	4mm Banana sockets

4.5.4 Current Amplifiers

a)	Setting range	6x 0 - 30A_{rms}
b)		3x 0 - 60Arms
c)	Single phase operation	1x 0 - 125A_{rms}
d)	Output power	6x 430VA at 25A
e)		3x 860VA at 50A
f)		1x 1000VA at 80A (LL-LN) or
g)		1x1740VA at 25A (L-L-L-L)
h)	Maximum compliance voltage	6x 35$V_{pk;}$ (higher is better.)
i)		1x 140Vpk (higher is better.)
j)	Accuracy	error < 0.05% of reading (0 - 32A) + 0.02% or range
k)	THD+N	< 0.015%
l)	Phase error	<0.05°

m)	Independent amplifiers	The six current amplifiers are to be independent from the four voltage amplifiers. The neutrals between the two current output groups are to be galvanically isolated (up to 2kV) to allow for series connection of the two groups in order to boost the compliance voltage.
n)	Connection	4mm Banana sockets

4.5.5 Low-level signal Generators

a)		6 additional analogue low-level signals to control external amplifiers or to test relays with low-level input, e.g. from Rogowski coils, linear voltage or linear current sensors shall be provided
b)		Full simulation of Rogowski coil signal (i.e. first order differential of signal) to be performed in hardware.
c)		Together with 10 internally used signal generators the system should provide 16 independent signal channels in total
d)	Output range	0 - 10 Vpk
e)	Accuracy	<0.025%
f)	Overload Protection	Yes
g)		The quantities displayed in the software shall be scalable for primary or secondary voltages (or currents).
h)		Couple to other auxiliary devices or possible synchronising function.

4.5.6 Signal Generation

a)		All outputs to be continuously and independently adjustable in amplitude, phase (0 to +/- 360°) and frequency.
b)		Able to generate continuous sine waves with a frequency between 10 and 1kHz and to generate transient files with a bandwidth from dc up to 3 kHz.
c)		Frequency error to be less than 0.5 ppm.
d)		Phase error to be less than 0.02°

4.5.7 Binary Inputs

a)	Number of inputs	10 galvanic isolated (2kV insulation voltage). *Supplier* to state the number of galvanic isolated inputs offered.
b)	Mode/Trigger criteria	Pick-up and drop-out of potential-free contacts or dc voltages of up to 600V. Trigger levels to be adjustable
c)	Max. Input Voltage	300V

d)	Max. error for pickup (energisation)	< 100 µs. *Suppliers* to state the time of error offered.
e)	Counting function	Inputs capable of counting number of pulses up to 3kHz. *Suppliers* to specify their offer.
f)	Connection	4mm Banana sockets

4.5.8 Analogue Inputs for Measurement

a)	Number	10 galvanic isolated (2KV insulation voltage). *Supplier* to state the number of galvanic isolated analogues offered.
b)	Input ranges	100mV, 1V, 10V, 100V, 600V
c)	Accuracy	<0.06%
d)	Bandwidth	dc.10kHz
e)	Sampling frequency	3kHz to 28kHz
f)	Overload protection	Yes
g)	Recording buffer	300s for 1channel at 3kHz, 3.5s for 10 channels at 28kHz
h)	Connection	4mm Banana sockets

4.5.9 Analogue low level measuring inputs for transducer testing

a)	Direct current range	Range 1: 0 - ±1 mA
b)		Range 2: 0 - ±20 mA
c)	Direct voltage range	0 - ±10 V
d)	Max. error	< 0.003%
e)	Connection	4mm Banana sockets

4.5.10 Auxiliary DC supply to power test objects

a)	Range	Range 1: 0 - 260 Vdc, 0.2A
b)		Range 2: 0 - 132 Vdc, 0.4A
c)		Range 3: 0 - 66 Vdc, 0.8A
d)	Power	Max. 50W (higher is better)
e)	Max. error	< 5%

4.5.11 Binary output contacts

a)	Number	4
b)	Breaking capacity	300V, 8A, 2000VA or 50W
c)	Type	Dry contacts that can be used to switch ac or dc

4.5.12 Time Synchronization

a) The test set should be able to synchronise to a GPS clock via a 1pps or IRIG B signal.

b) Timing accuracy for 1pps / IRIG-B: 1 μs.

c) Maximum distance between GPS receiver and test equipment for 1pps signal: 40m.

d) Test set needs to be synchronised to the IEEE 1588 Precision Time Protocol (PTP) via Ethernet and conform to IEC61850-9-3, IEEE C37.238-2011 and IEC61588.

e) Timing accuracy for PTP: 100ns.

f) Maximum distance between GPS receiver and test equipment for PTP: 2000m.

g) IEEE 1588 / PTP clock to be powered over Ethernet (PoE), i.e. no separate power supply should be necessary.

4.5.13 Interface to PC

a) Interface to the Windows 10 PC via Ethernet interface or USB

b) 10/100Mbit/s copper (auto sensing, auto crossover) via RJ45 connector alternatively USB. (10/1000Mbit/S shall be preferred and is essential where the test set processes sampled values)

c) Two Ethernet communications ports to support communication on a process bus (IEC61850-8-1 (GOOSE), IEC61850-9-2 (Sampled Values) and UCA2.0 AND station bus at the same time. PTP to IEEE 1588 and IEC61850-9-3.

d) Communications card to support IEEE 1588 / Precision Time Protocol (PTP) and IEC61850-9-3 to synchronize the test set to a PTP enabled Grandmaster clock in the substation for End-to-end tests / Synchrophasor tests.

e) Centronics parallel port (LPT) and/or serial RS232 ports are not permissible as modern laptops do not provide such ports.

4.6 Software

4.6.1 General

a) Windows 10 (32bit & 64bit) / 7(32bit & 64bit) software, upgradeable to the latest version available from Microsoft. Long filenames, tool tip help, context sensitive menu function (right mouse click) and an integrated help browser shall be provided. All future versions of Windows operating systems within the lifespan of the hardware to be supported.

b) All software functions, options and actions should be easily available by click of a button and/or shortcut key to avoid having to navigate through complicated menu structures and having to drill through multiple menu levels. The Microsoft ribbon-based menu structure used in Office 365 is an example of sorting all functions, options and actions and making all easily accessible in the right place.

c) No programming to be necessary to test an application - entry of setting parameters to be all that is required to set up and perform a test.

d) Future expansions in functionality by means of software updates. Firmware updating to be handled by the software, i.e. exchange of any hardware components is not permissible.

e) Generation of reports on paper or file. All graphics and text to be printable.

f) Test report shall be configurable to include custom information in graphical format (e.g. logos, wiring diagrams) and text format (tester, date of test, substation, reminders). Once a test report is generated, it shall be time stamped and will not be editable.

g) The test set software should be able to import relay settings records from OEM relay setting software currently used by the *Purchaser*, in a format compatible with the test set.

h) It shall be possible to test multi-function relays / scheme with one test routine / document.

i) Test sequence shall allow a pause in the test sequence at pre-defined points, by popping up a custom instruction dialogue (with or without audible warning), instructing the user to change either a setting on the relay, change of hard wiring or to record a specific measurement / status from the relay / scheme.

j) All testing to be in closed loop.

k) Online Pass/ Fail assessment for ALL tests. This is particularly important for automatic testing.

l) Full automatic testing shall be possible, i.e. without launching various test modules manually.

m) Allow for tolerances to be adjusted in the test templates, for example an adjustable range from 0% to 15%.

n) MFT Software shall not be hindered by the use of anti-virus software eg. Mcafee/Norton.

4.6.2 Manual Control Function

a) Direct entry of actual relay settings into test software. Test specific parameters (e.g. set I1 to 110% of I>>) shall be automatically re-adjusted according to the entered relay settings.

b) Manual and independent adjustment of amplitude, phase angle and frequency for all generator outputs.

c) Graphical display of natural voltages and currents in a vector diagram.

d) Direct entry sequence components and graphical display in a vector diagram

e) Direct entry of impedances and graphical display in a R/X diagram

f) Direct entry of power and graphical display in P/Q diagram

g) Ramping and stepping of any of the above quantities: all phases at the same time.

h) Synchronized switching of multiple variables at the same instance in time.

i) Timing functions for pick-up and drop-out measurements.

j) On-line Reporting Function

k) Synchronise generator outputs to any third-party signal, e.g. mains frequency.

l) Full control of voltage and current. Full control of amplitude and frequency. Any test required by a MFT shall be possible using manual control.

4.6.3 State Sequencer Function

a) Direct entry of actual relay settings into test software. Test specific parameters (e.g. set I1 to 110% of I>>) shall be automatically re-adjusted according to the entered relay settings.

b) Manual testing.

c) Fully automatic testing.

d) Ability to generate test sequences from any number of states. Each state consists of any combination of voltage, current, frequency and any binary output state.

e) Graphical display of natural voltages and currents in a vector diagram.

f) Graphical display of voltages, currents and binary signals over time.

g) Direct entry sequence components and graphical display in a vector diagram

h) Direct entry of impedances and graphical display in a R/X diagram

i) Direct entry of power and graphical display in P/Q diagram

j) Define trigger conditions for each state either in fixed time or dependent upon a logical combination of the binary inputs for accurate timing measurements.

k) Synchronization to GPS / PTP and other digital timing pulses.

l) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.4 Linear Ramping and Step Ramping Functions

a) Direct entry of actual relay settings into test software. Test specific parameters (e.g. set I1 to 110% of I>>) shall be automatically re-adjusted according to the entered relay settings.

b) Manual testing.

c) Fully automatic testing.

d) Ability to linearly ramp up to two independent variables (e.g. voltage and frequency) at the same time, while keeping the other quantities at a defined constant value.

e) Ability to ramp a single variable in a stepped fashion i.e. ramped quantity shall be set back to a predefined value between every step to allow the relay to reset.

f) Graphical display of natural voltages and currents in a vector diagram.

g) Graphical display of voltages, currents and binary signals over time.

h) Define trigger conditions for pick-up / drop-out measurements upon a logical combination of the binary inputs.

i) Synchronization to GPS / PTP and other digital timing pulses.

j) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.5 Transient Playback Function

a) IEEE COMTRADE (C37.111-1991) compatible (ASCII and binary formats).

b) Synchronization to GPS / PTP and other digital timing pulses.

c) Recording playback sampling rate of up to 4.8kHz (minimum). Down sampling to be supported.

d) Graphical display of voltage and current traces as well as digital signals and relay responses.

e) Editing of signals: Extending (repeating) and deleting portions of the recorded signal.

f) Ability to generate composite harmonic wave shapes.

g) Ability to edit own digital signals in the COMTRADE file. The test set software must allow existing binaries to be played back to outputs.

h) Minimum length of Comtrade files to play back shall be 10 minutes.

4.6.6 Overcurrent Relay Testing

a) Direct entry of actual relay settings into test software. Test specific parameters (e.g. test points) shall be automatically re-adjusted according to the entered relay settings.

b) Manual testing.

c) Fully automatic testing.

d) Testing of the operating characteristic (trip time vs. current test) for all types of fault (earth faults, phase faults, negative sequence and zero sequence faults)

e) Display of overcurrent characteristic and test points in I/t diagram.

f) Determine the pick-up and drop-out current for all fault types.

g) Determine the pick-up and drop-out of directional characteristic for directional overcurrent relays.

h) Breaker simulation: Simulate the 52a and 52b auxiliary contacts of a breaker with the binary outputs, switch the currents off at zero crossing of current after a trip signal has been received.

i) Characteristic formulae: IEC255-4, BS142 and IEEE PC37.112-1995, I^2t characteristics to be supported. Definition of custom characteristics shall be possible.

j) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.7 Frequency and Voltage Relays Testing

a) Direct entry of actual relay settings into test software. Test specific parameters (e.g. test points) shall be automatically re-adjusted according to the entered relay settings.

b) Manual testing.

c) Fully automatic testing.

d) Generation of ramps for amplitudes, phase angles and frequency.

e) Pick-up, timing and stability tests.

f) Graphic and tabular display of relay pick-up and drop-out vs. time.

g) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.8 Distance Relay Testing

Testing of line impedance relays and field failure characteristics on generator protection relays.

a) Importing / manual entry of the actual relay settings of a distance relay into the test software. A few examples of these relays are ABB REL 670/RED670/511/531; SEL 321/421; Alstom Quadromho, Optimho, Micromho; Siemens 7SA511/3, 7SL27, R3Z27; GEC YTG, PYTS; BBC LZ32. The tripping characteristic shall be generated automatically for each of the above relays. All new IED's should be fully supported by the MFT *Supplier*.

b) Impedance characteristics supported: Quadrilateral, Mho, Tomato or Lens characteristic.

c) Manual testing.

d) Fully automatic testing.

e) Test the trip time at specific fault impedances. Fault impedances shall be specifiable in relation to zone reaches, e.g. 90% of Z1. Automatic assessment of whether the tested trip time has passed or failed.

f) Check the reach of a relay by placing a fault shot at the inner and outer tolerances border (i.e. theoretical reach minus and plus the defined reach tolerance of the relay). Automatic assessment of whether the tested reach has Passed or Failed.

g) Automatically test the characteristic in the impedance plane (R/X diagram) and/or in the time grading diagram (Z/t diagram). Automatic assessment of whether the tested reach has passed or failed.

h) Test models supported: constant test current, constant test voltage and constant source impedance.

i) DC offset simulation: Control of angle of fault incidence, time constant of dc offset to be calculated on-line from system parameters (R/L).

j) The separate arc resistance algorithm is to be supported for both earth faults and phase faults (as implemented on numerical distance relays).

k) Apply Pre-fault voltage, i.e. duration settable.

l) Breaker simulation: Simulate the 52a and 52b auxiliary contacts of a breaker with the binary outputs; switch the currents off at zero crossing of current after a trip signal has been received.

m) Graphical display of analogue voltages and currents plus relay contact responses vs. time.

n) Display of injected voltages and currents on a vector diagram in natural and/or in symmetrical components.

o) Testing of auxiliary functions: Manual close, power swing, Auto-reclose function, VT fuse fail.

p) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.9 Differential Relay Testing

Testing of transformer differential relays, line differential relays, motor / generator differential and busbar differential relays.

a) Importing / Manual entry of the actual relay settings of differential relay directly into the test software. A few examples of these relays are ABB RET670/RED670/SPAD 346, Reyrolle Duobias, SEL 387/487/587/787, Reyrolle Duobias M and Siemens 7UT51. The operating characteristic shall be generated automatically for each of the above relays. Any new differential algorithm that is introduced shall be accommodated in a reasonable time period; typically this should be at no cost to the purchaser.

b) Manual testing.

c) Fully automatic testing.

d) Simulation of two and three winding transformers for all possible vector groups (e.g. YY0, YD1, YD11, etc.).

e) Testing the operating characteristic (Idiff vs. Ibias) for all types of faults: earth fault, phase faults and three phase faults.

f) The various types of Ibias formulae (Ibias = (|Ip|+|Is|)/k; Ibias =max(Ip,Is); etc; numerical zero sequence elimination and both reference side have to be supported.

g) Testing the harmonic restraint characteristic (Idiff vs. %I harmonic) for second harmonic (inrush restraint) and fifth harmonic (over fluxing restraint).

h) Testing of the inrush restraint characteristic for relays which utilize the gap detection technique.

i) Testing the trip time characteristic (trip time vs. Idiff) for all types of fault.

j) Test the stability of the relay to confirm the correctness of the vector group correction, CT mismatch correction and zero sequence elimination.

k) Apply pre-fault current, i.e. through fault current condition. Test current and duration settable.

l) Apply voltage in addition to six currents - according to HV or LV voltage

m) GPS / PTP synchronized End-to-end tests to test the operating characteristic of line differential relays, i.e. by simulating either the local or remote end of a line.

n) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.10 Synchronizing Devices

a) Importing / Manual entry of actual relay settings into test software. Test specific parameters (e.g. test points) shall be automatically re-adjusted according to the entered relay settings.

b) Manual testing.

c) Fully automatic testing.

d) Adjustment control mode to be tested closed loop.

e) Graphical display of quantities in a $\Delta V/\Delta f$ diagram as well as relative phase angles in a synchronoscope.

f) Feedback signals: closing pulse and adjustment pulses (V+, V-, f+, f-). Display of adjustment controls vs. time.

g) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.11 Testing with GOOSE Messages

a) All the above protective relay test modules shall support testing for IEC 61850-8-2, i.e. be able to trigger on GOOSE messages as well as simulate GOOSE messages (if need be). Test set to support subscription to Logical Nodes as per IEC 61850-7 (All sub-parts).

b) Import of SCD, ICD of GOOSE sniffer files to configure the triggering / simulation of GOOSE messages.

c) Simulation and subscription of up to 360 simultaneous GOOSE messages shall be possible.

d) GOOSE performance to IEC 61850-5 and processing time to Network and to Test set better than 1mS.

e) VLAN support (selectable priority and VLAN-ID

4.6.12 IEC61850 Digital Substation Network Tests, Monitoring, Simulations & Cyber Security Tools

a) *Suppliers* shall propose additional hardware and/or software tools to allow for IEC 61850 substation network monitoring, analysis, diagnostics, MMS communication, GOOSE communication, simulation-based, distributed protection testing and/or detection of malware or other cyber security threats present on the network, which can be used during commissioning and maintenance.

b) The tool shall be capable of acting as an IEC61850 client and server; perform automated testing, allow for signal tracing, signal testing and perform simulations, in particular for IEDS which are not present in the digital station.

c) The tool shall be interoperable with all IED manufacturers equipment.

d) The tool shall be capable of importing/exporting IEC 61850 configuration files from different manufacturers, eg. SCD, ICD, CID files; for use in simulation and testing

e) The tool shall be capable of connecting and testing more than 80 IEDS within a typical substation environment. *Suppliers* to state the limitations.

f) Where additional hardware; software or licenses are required, then separate costing shall be provided.

4.6.13 Testing with Sampled Values

a) All the above protective relay test modules shall support testing for UCA Guideline IEC 61850-9-2LE, IEC 61869-9 and IEC 61850-9-2, i.e. be able to simulate all voltages and currents as Sampled Value signals.

b) Simulation of up to THREE sets of IEC61850-9-2LE signals shall be possible.

4.6.14 Testing Single and Three Phase Transducers

a) Manual testing.

b) Automatic testing.

c) Generation of sweeps for amplitudes, phase angles, frequency, power (W, VA, Var).

d) Individual setting of voltages and currents (ito amplitude, phase angle and frequency) should be possible per test point.

e) For single phase transducers phase injected should be selectable.

f) L-L voltage transducers to be tested with full three phase voltage system.

g) On-line calculation of error (absolute, percentage and full-scale).

h) Display of transducer output and absolute, percentage and full-scale errors vs. sweep quantity graphically and/or as table.

i) Feedback signal: Low-level analogue voltage (0 - +/- 10V) or current (0 - +/-20mA)

j) Automatic assessment of test results (Pass / Fail) with actual results and deviation from nominal.

4.6.15 Power Quality Signal Generator to NRS048-2 / SANS/IEC61000-4-30; SANS/IEC61000-4-7; BS EN/IEC 61000-4-15 and IEC62586

a) Testing of Power Quality measurement devices as per the NRS 048 standard.

4.6.16 On-line Multi-meter Measurement Function

a) Up to 10 independent inputs

b) Software to display amplitudes and phase angles of ac voltages and currents, symmetrical components of voltages and currents, line to line voltages, frequencies, power (active, reactive and apparent) and cos(phi) independently for each input.

c) All ac measurements to be true RMS.

d) On-line vector diagram for voltages and currents as well as power.

e) On-line measurement of Vdc, Idc and dc power for each input.

f) On-line display of harmonics measured both numerically (in a table per harmonic frequency) and graphically in a bar graph.

4.6.17 Transient Recording Function

a) The recording function should enable recordings at the specified sampling frequency.

b) Any recordings done should automatically be uploaded to the controller PC.

c) The recordings should be saved in COMTRADE format on the PCs hard drive.

d) Trigger conditions: amplitude, swell and sag, harmonic, frequency, frequency change, notch as well as any combination of these triggers.

e) A pre-trigger buffer should be definable.

f) Analysis software should be provided to analyse the recorded wave shapes in terms of analogue wave shapes (RMS and instantaneous values), vector diagram, impedance plots (L-N and L-L fault loops) as well as harmonics.

g) For impedance plots, the relays impedance characteristic should be displayable in relation to the impedance trajectory measured by the relay.

4.7 Energy Meter Testing

The Multi-function Test Set for energy meter testing can be a separate test set or option/module within the Secondary plant MFT. The MFT shall be able to handle the testing of meters for both three phase three wire and three phase four wire configurations for current transformers operated meters both at 1A and 5A.

The MFT for energy meters shall be made up of the following components:

- Source
- Reference/working standard
- Scanning head
- Test software

The MFT shall be able to test energy meters using the existing network load or at specific load points utilising the MFT source. The MFT shall facilitate both manual and automatic testing of energy meters.

4.7.1 Source

THE MFT source for energy meter testing shall comply with the requirements specified in the following sections of the standard:

a) 4.1 Power Supply

b) 4.2 Dimensions and Weight

c) 4.3 Environment

d) 4.4 Certificates

e) 4.5.1 General Hardware

f) 4.5.2 Output Amplifiers

g) 4.5.3 Voltage Amplifiers

h) 4.5.4 Current amplifiers

i) 4.5.9 Analogue low level measuring inputs for transducer testing

j) 4.5.13 interface to PC

4.7.2 Reference/Working Standard

The reference/working standard shall be capable of performing single and three-phase measurements with and accuracy class of 0.05% for active energy and 0.2% for reactive energy. The reference/working standard shall have the required accuracy to test class 0.1 S metering devices. The *Purchaser* and SANS/IEC standards that the *Supplier* shall prove the suitability of the reference/working standard to test a class 0.1 S energy meter are as follows:

1) 240-77224537: Standard for Calibration and Limits of Errors for Single and Three Phase Energy Meters

2) SANS/IEC 62052-11: Electricity metering equipment (a.c) – General requirements, tests and test conditions Part 11: Metering equipment

3) IEC 62053-22: Electricity metering equipment (a.c) – Particular requirements Part 22: Static meters for active energy (classes 0,1S, 0.2S and 0,5S)

4) SANS/IEC 62053-24: Electricity metering equipment (a.c) – Particular requirements Past 24: Static meters for reactive energy at fundamental frequency (classes 0,5S, 1S, 1, 2 and 3)

5) SANS 474: Electrical metering – Standard requirements

It is preferred that the reference/working standard be a separate module or detachable from the MFT to facilitate its calibration.

The following requirements shall apply to the reference/working standard

Parameter	Value
Voltage measuring range	0V to 300V (L-N)
Current measuring range	0 to 10A
Frequency range	45 Hz to 65 Hz
Measurement mode for single phase meters	1 phase 2 wire active / reactive
Measurement mode for three phase meters	1 phase 2 wire active / reactive 3 phase 4 wire active / reactive 3 phase 3 wire active / reactive

4.7.2.1 Reference/Working Standard Power Supply (If separate unit)

The power supply for the reference/working standard, if the reference/working standard is a separate unit shall comply with the requirements specified in section 4.1 of the standard

4.7.2.2 Reference/Working Standard Functionality

The reference/working standard shall provide the following functions:

a) Measurement of electrical parameters including voltage, current, active, reactive and apparent power, active, reactive and apparent energy, frequency, phase angle, power factor and harmonics

b) Error calculation utilising the pulses counted from the meter and provide an indication of the percentage error of the meter under test.

c) Vector diagram, harmonic analysis and wave form display

d) Current instrument transformer tests: ratio and burden

e) Voltage instrument transformer tests: ratio, burden and voltage drop

4.7.3 Test Software

The test software shall comply with the general requirements specified in section 4.6.1 of the standard with the following additions:

a) The software shall allow generating and storing test programs. It shall be possible to adapt the programs to different meter types, nominal values and ranges of current and voltage.

b) The software shall allow automatic or manual (step-by-step) execution of test programs.

c) It shall control, display and log the test parameters, such as connection mode, voltages, current, frequency, phase angles, power factor, power and energy.

d) The software shall monitor the operation of the MFT during execution of the program and if parameters are outside the acceptable limits, give a warning or alarm and/or abort the program.

e) The software shall provide information on the status, for example “Initialisation”, “Measurement running”, “Waiting for input from operator”, “Aborted”, “Finished”, etc.

f) The software shall automatically calculate the errors and evaluate the results of the tests for each test point. It shall display and print the results and store them with proper identifiers for further processing.

g) The software shall be able to generate vector diagrams, harmonic analysis and wave form displays, print and store them in graphical format with proper identifiers.

h) The software shall be able to perform instrument transformer tests (ratio, burden and voltage drop test for voltage instrument transformers), print and store the results with proper identifiers.

4.7.4 Scanning Head

The receiver diode of the scanning head shall be capable of sensing optical output according to SANS/IEC 62052 -11 clauses 5.11.1 and 5.11.2

4.7.5 Error Calculation System

The error calculation system shall be able to count pulses and to calculate and indicate the percentage error of the energy meter under test. The error calculation system receives pulses from the scanning head and compares those with the pulses received from the reference/working standard.

The system shall have the following standard functions:

a) The system shall provide an automatic assessment of the results (pass/fail) and indicate the error along with the sign (+ or -)

b) A reset function shall be available allowing to reset the error indication in the case the error measurement is incorrect, for any reason

c) The system shall provide the parameters of the error calculation process for verification purposes

Additionally, the error calculation system shall adhere to the following requirements:

Parameters	Value
Pulse frequency range, which the system shall be able to count	0 to 1 kHz

Resolution of error indication	Minimum 0,01%
Indication of error	+/- indication, numbers along with %
Accuracy	+/- 1 digit of the lowest significant digit

4.8 Software Licensing

a) A software license shall cover all operating system versions where the functionality is similar. The future of desktop operating systems is hanging in the balance; end users should have experience with other operating systems such as mobile operating systems. Investment in software should be for the function not the operating system type.

A software license shall not depend on a hardware dongle to be used. The License shall be imbedded in the software and the *Purchaser's* license shall be embedded in the software package such that any employee of the *Purchaser* may control a test set of another employee using his / her own computer and test set software, it is accepted modules are registered per test set and that certain functions may not be available to another user. Dedicated software for use with say an IEC61850 package shall also not use a dongle. The license shall be applied such that a user can transfer the license to other computers.

4.9 Local Support

a)	Hotline support hours	Local telephonic support to be offered in the hours of 07h00 - 20h00 South African time.
b)	Electronic communication support	Any form of electronic communication to be offered with a guaranteed turnaround time of 1 business day, e.g. MS Teams.
c)	Number of units in operation in South Africa	10 units in SA (separate list of users with contact details to be provided)
d)	No of back-up units available in South Africa	2 (Full Specification Test Set)
e)	SANAS registered Calibration facility available in South Africa	Yes
f)	Guaranteed turnaround time for repairs and calibration	< 14 working days (Sending units offshore for repair shall be the exception)
g)	Product training offered in South Africa	Standard training offered on request. In-house / On-site training to be offered on request Standard training to be offered as a registered course with Eskom Academy of Learning.
h)	Warranty on Hardware	Five years from date of delivery

5. MFT hardware configurations

It is expected that more than one *Supplier* will be allocated to supply tests sets (this is the intent, but other factors may preclude this) and all products meeting the five configurations and being technically and commercially acceptable will be considered as per commercial processes.

Suppliers matching the requirement best will improve their chances of making the final selection. It is essential to break down pricing where possible to individual options. As an example, if the test set can do transient playback of Comtrade files this should be listed as an option. If this is a standard part of the package it shall be clearly stated. Each option as priced shall have the functionality fully detailed. Generally, functions such as Comtrade file play back are viewed as software functionality although the hardware is key to the realisation of the functionality. These aspects will be accounted for as well in an evaluation. The five hardware packages listed shall indicate compliance with the basic and intermediate software packages and any deviation clearly indicated. All advanced software module capability shall be listed with each hardware offer, including modules not described in this standard. Where the advanced modules listed in this document are not available this shall be clearly indicated in the deviation schedule.

The hardware *Supplier* shall ensure that the MFT platform is upgradeable and that the end user may upgrade a MFT to take advantage of newer hardware features. Thus, the hardware design shall be modular. A realistic time frame shall be 15 years from contract approval; thus, any new software features shall be available with this platform.

Local technical support (Test set based and testing of different IED's) and local repair will rank highly in the outcome of the technical assessment.

Quality of the hardware and software as well as ease of use also ranks highly in the outcome of the technical assessment. Thus, each *Supplier* shall add proof of this in the document package where possible. This may include factors such as failure rate, MFT's sold to the world market per country.

The following test set configurations are to be catered for:

Note: *Supplier* shall offer a test set that meets or exceeds a particular category. It is understood that different *Suppliers* will have similarities and also differences to what the *Purchaser* requests. The *Purchaser* shall have to categorise test sets deemed suitable for end users to procure. The end user will select test sets on offer based on own technical requirement and budget.

5.1 Universal three phase test set

Comprising of a 3 phase voltage and current output (L1, L2, L3, N) plus 4 binary outputs, auxiliary DC supply, analogue input for ±10V and ±20mA, 10 binary and analogue inputs. (Preference for additional single phase voltage channel or better)

5.2 Universal six phase test set

Comprising of a 2 x 3 phase current and 1 x 3 phase voltage output (L1,L2,L3,N) plus 4 binary outputs, auxiliary DC supply, analogue input for ±10V and ±20mA, 10 binary and analogue inputs. (Preference for additional voltage channel or better)

5.3 Universal six phase test set, additional 3 Phase Voltage channel

Comprising of a 2 x 3 phase current and 2 x 3 phase voltage output (L1,L2,L3,N) plus 4 binary outputs, auxiliary DC supply, analogue input for ±10V and ±20mA, 10 binary and analogue inputs.

5.4 Universal Single phase test set

Comprising of a dual single phase current channel, with one current output shall be usable as a voltage output, one binary input and one binary output. Units slave together, up to at least nine dual channels (Current and Voltage).

It is expected that test set *Suppliers* might not be able to match the four expected configurations and some options may not be realisable at all.

5.5 Energy Meter Test Set

The requirements for the energy meter test set are detailed in section 4.7.

A metering test set may not require all the protection functionality, therefore a standalone cost-effective test set for metering may be proposed.

The MFT for energy meters shall provide for the following configuration options:

5.5.1 Universal three phase test set with refence/working standard

Comprising of an integrated/modular 3 phase voltage and current output (L1, L2, L3, N), analogue input for ±10V and ±20mA, reference/working standard capable of performing single and three phase measurements for testing class 0.1 S meters and scanning head.

5.5.2 Standalone universal three phase test set

Comprising of a standalone 3 phase voltage and current output (L1, L2, L3, N) and analogue input for ±10V and ±20mA

5.5.3 Standalone reference/working standard

Comprising of a standalone reference/working standard capable of performing single and three phase measurements for testing class 0.1 S meters and scanning head.

The units may possibly be specific for metering and shall be listed as such.

6. Software

The software is detailed in item 4, “Detailed technical and software specification”. This section complements item 4.

The software shall be compatible with Microsoft Windows 10, Windows 7, 32 bit and 64bit and all newer versions as released by Microsoft in the future. Where complementing software is available such as for mobile computing platforms and the software performs the same or similar function as the Windows licensed software this should be seen as part and parcel of the licensed software and inclusive with the software license cost.

The software shall be available on the manufacturer’s web site. The manufacturer or local agent shall keep the *Purchaser* abreast of all changes and detail the reason for a change. The *Purchaser* favours free software maintenance updates, thus minor function and / or interface enhancements shall not necessarily indicate a new module. Usually updated versions of software are released to correct software errors, accommodate newer operating systems and to streamline and enhance the MFT operator user interface. New modules are excluded; a new module is seen as new test functionality and not enhancement or bug fixes. Each *Supplier* shall detail all aspects of the software and when charges to the end user will be made necessary.

Should a software module require a specific hardware accessory or multiple accessories this shall be included in the price of that specific module, at the very least the software module should detail the available accessories in cases where the accessory is user use case dependent.

The communication link between the PC, the controlling software and the test set shall be in order of preference or a combination thereof:

1) Ethernet via RJ 45 Copper

2) USB cable

Software packages that have built in security such that if a test set is stolen and reported to the manufacturer (by the customer, complete with the necessary security checks), the test set shall become inoperable to non-*Purchaser’s* employees. *Suppliers* can propose security measures that mitigate against the hardware from being stolen, and software downloaded from the *Supplier* website, thereby preventing the test set being used by non-*Purchaser* employees.

If an alternative Operating System of the test software is available and the software has the same functionality as the Windows version this should be available as part of the of the Windows based software package. With the volatility of the operating system market this allows users to adopt alternative software early. Typically this would be mobile based operating systems. The *Supplier* shall price independently each software module in addition to the Basic and Intermediate software package. This will also include any advanced software packages such as network simulation software that may or may not run independently from the traditional MFT software suite.

Where the software is sold separately from the hardware package the software should be packaged in the following manner:

6.1 Basic software package

a) Manual control as defined in item 4

b) Overcurrent and Earth fault module as defined in item 4

c) Frequency and voltage relay testing as defined in item 4

d) Energy meter testing as defined in section 4.7.

Note: Additional functionality may be included.

6.2 Intermediate software

This software package is the same as the basic version, but the following modules shall be included:

a) Ramping module and the pulse ramping module as defined in item 4.

b) State Sequencer as defined in item 4

c) Line and Transformer Differential module as defined in item 4

d) Line Distance module as defined in item 4

e) Transducer (single and three phase) testing as defined in item 4

f) Transient playback of Comtrade files as defined in item 4

g) In accordance with IEC61850, GOOSE trigger and simulation as defined in item 4

h) In accordance with IEC61850, Sampled Values simulation as defined in item 4

i) Energy meter testing as defined in section 4.7

6.3 Additional advanced modules

This software package shall be separate from the intermediate package, and procured as required by the end user.

a) All software functionality as indicated in the basic and intermediated.

b) Dedicated recloser testing modules

c) Synchronising modules as defined in item 4

d) Transient recording function as defined in item 4

e) On Line multi-meter function as defined in item 4

f) Power Quality measurement device testing based on NRS048-2 / SANS/IEC61000-4-30; SANS/IEC61000-4-7; BS EN/IEC 61000-4-15 and IEC62586. In essence NRS 048 is the standard followed in South Africa and the *Supplier* shall state whether the test module is fully compliant with the NRS 048 standard.

Note: The above modules shall be purchased individually or as a composite of any other module. For example, a metering test set may comprise of the basic module and the relevant metering related modules. The purchaser shall thus have the option of purchasing any modules as required with a hardware option, for example a metering compliant version of a test set and only the manual control module and the dedicated metering related software modules.

6.3.1 Other advanced software

Any other module available shall be detailed and offered. The two packages and advanced modules are offered to provide a useful compilation of packages at a competitive price. The advanced options as required and where available. Examples of modules/additional hardware not listed are network simulation software, IEC 61850 substation network monitoring/diagnostic tools, MMS communication, simulation-based and distributed protection testing using multiple test sets.

In the detailed technical section and when evaluating hardware pricing, the advanced features will not be factored in the pricing evaluation. As previously explained the *Purchaser* may alter the cost evaluation method but will endeavour to compare cost in a fair and equitable manner. It is hoped that the advanced features will not be used to negate a fairly priced package.

The benefit of the advanced modules would be the possibility that the MFT system is given priority as it will benefit specialist MFT users in certain parts of the organisation.

7. Accessories

Test sets come with multiple accessories and thus all options will not be detailed. The following items shall be in the accessory basket:

7.1 Standard accessory package with a MFT:

a) Each test set to be equipped with a set of 2m; 2 mm² (minimum length) test leads sufficient to populate all inputs/outputs

b) A combination test lead with the 4 current and voltage leads, thus 8 leads in total clearly marked for current and voltage application and suitably colour coded. This lead shall be long enough to plug into the current and voltage channels and reach the current and voltage test points on a typical protection or metering scheme.

c) Connectors for each lead to allow a sound connection to the devices under test.

d) A quality carry bag made of a durable material with carrying strap or other quality case. The bag or container shall easily house all the leads and accessories.

e) A hardened transport case with wheels to facilitate easy transport and sufficiently sturdy to be used for multiple shipping events. Lockable.

f) The required communication cables

g) Manual, the manual may be part of the software module or a software copy. The manual shall be fully detailed. The manual is to cover both the hardware and the software. The manuals may be two separate software documents. The Test set manuals shall preferably be imbedded in the test set control software and have an auto update facility when connected to the Internet.

h) Should a software module require a specific accessory to complete or execute a test the test set package shall come equipped with the required accessory and be accordingly priced.

i) A calibration certificate. See the details under the calibration section.

7.2 Examples of other Accessories or services:

a) The listed examples are currently used by the *Purchaser*, however ALL useful software modules and accessories on offer to be listed and priced in terms of the contract pricing structure and period.

b) Clamps, crocodile clips, terminal connectors.

c) Clip on current transducers for test sets with current measurement/recording capabilities.

d) GPS time synchronisation devices and all accessories required to execute the time synchronisation function. All offerings such as dedicated units and PTP based units.

e) ARC sensor light emitter. (Electrical arc protection scheme testing)

f) Sensors to accommodate measurement of all types of meters. (Pulsing LED signals)

g) Additional communications cables and other specialised cables.

h) Software modules

i) Calibration service to SANAS requirement, priced for all test set offerings including return shipping.

j) Repair / Calibration return shipping, however this is usually included in the repair / calibration cost and shall be the preferred method.

k) High voltage testing protective devices (e.g. Power Transformer testing) such as metrosil / varistor type protection

l) Switch boxes

m) Test set controllers with on board software (Not a PC)

n) Dedicated cables to match reclosers etc.

o) Dedicated recloser test software

p) Hardware upgrades

q) Any other useful accessory or software module

8. Calibration, Repair and Annual Reports

Test set *Suppliers* shall offer a local calibration and repair service for all test set equipment and accessories. Repairs may include upgrades that need *Supplier* installation.

8.1 Calibration for test sets provided

Calibration shall be done in accordance with the standard “240-76624513: Standard for calibration of test instruments used by field staff” and/or “240-95637584: Work instruction for control of monitoring and measuring equipment”. The *Supplier* may sub-contract this service.

Suppliers to propose methods of on-site calibration, if possible.

The manufacturer of the test equipment shall provide a letter for each item of hardware requiring calibration indicating a realistic interval in years between calibrations. The end user is responsible to assess whether the recommended interval needs to be shortened due to the criticality of the test process or possible early hardware failure.

Calibration shall be a standard contract item and shall cover the calibration service and the return transportation of the test set to the user. The transportation service shall include insurance should the device be lost or damaged in transit. The device will be shipped in a secure container.

A certificate of calibration shall be supplied with the returned test set. The calibration certificate shall reference the Lab no. and Company name with the SANAS accreditation. The test set shall also have a dated calibration sticker attached including a recommended future calibration date. This sticker should be applied such that any interference with the test set innards shall not damage the sticker. Preference shall be for two stickers situated at opposite sides of case opening seam. The calibration certificate shall at minimum detail the following:

a) Name of calibration facility

b) Certificate number

c) Calibration date

d) MFT description

e) MFT serial number

f) Instrument(s) used for calibration

g) Calibration detail of reference instrument(s)

h) Table of calibration results for instruments

i) Recommended future calibration date.

8.2 Repair

For repairs out of warranty, the end user shall ship the faulty unit to the *Supplier*. The end user shall be responsible to accept the quotation and generate a purchase order for out of warranty repairs. The *Supplier* shall not proceed with the repair before an official order from the *Purchaser* is received for the quoted repair. The *Purchaser's* personnel shall be discouraged from sending units in for calibration or repair without a valid purchase order or Commercial approval.

8.3 Annual Reports

The *Supplier* shall keep accurate record of all calibration and repair services provided regardless of the unit guarantee status (Thus defective/damaged devices within the guarantee period are included in all reports.). An annual report shall be made available to the contract manager. The report shall include all historical failures associated with the *Purchaser*. The contract manager may request a report at any time; however this would be the exception.

The *Supplier* is encouraged at his/her discretion to engage with the *Purchaser* at any time to take up issues such as abuse of test sets.

The report shall detail at minimum the following:

a) The Make

b) The model

c) The Serial number

d) The age of the device

e) In or out of guarantee

f) Guarantee honoured (Yes/No)

g) Reason for not honouring a guarantee claim

h) The end user by name, unique no. and also the Group and Section

i) The condition of the device as received relative to age (Thus Excellent, Good or Poor)

j) The nature of the failure

k) The turnaround time in days

l) Repair cost

m) History of repairs/calibration conducted to date.

n) Any other remarks

o) The number of units of each type sold in each calendar year

9. Training

Physical or Virtual Training shall be offered on both the software and the hardware and offered at least quarterly. Preference shall be that the training is registered with the *Purchaser* as an official training course. Training to be offered at the respective *Purchaser*'s premises where the training requirement exceeds 7 trainees. The minimum charge in such cases will be for 8 trainees.

Courses are to be done by the trainee attending with the Purchaser supplied Laptop and correct version of software.

The training shall be offered in modules as discussed below:

9.1 Basic Training Course

Here the manual operation of the test set via the PC based software module and/or hardware controller. Testing of over current, earth fault, voltage and frequency relays as per basic test set configuration. Training shall be comprised of a hardware overview, safety aspects. Discuss calibration and repair aspects and why this is necessary. Provide software training, software installation process and lastly the licensing aspects of the test system.

The following minimum test set training shall be provided; manual testing of a modern overcurrent, voltage and frequency measuring IED using the manual testing software module and the associated software modules. Each student shall do hands on testing with a test set and an IED, preferably using an example of an IED on the *Purchaser's* contract. The training shall also include directional overcurrent elements and explore the differences in terms of directionality by different vendors. Typical protection functions found in a modern direction over current IED shall also be covered in as far as the manual software allows. (Typical examples are under frequency, under and over voltage, thermal over current).

9.2 Intermediate Training Course

As per the intermediate software package all intermediate modules as specified in the intermediate software package shall be included in the training. Hardware setup and hands on testing of with all modules shall take place. It is accepted that the students have done the basic training. The course may be split into two manageable time slots.

9.3 Metering and Measurements Training Course

This course shall cover the basic course detailed above but exclude the overcurrent relay testing. The course shall focus on the testing of energy meters both electromechanical and digital devices as well as the testing of digital transducers.

9.4 Advanced Training

Advanced training shall be offered on all modules included in the advanced software option list including all additional software modules listed by the *Supplier*.

The training provided for a specific advanced module may be included with the basic or intermediate course on request from the end user; this usually would include a group of people.

Advanced training may for example be set up for testing IEC 61850 based systems, including the relevant substation network analysis tools. Advanced training to include advanced template/test sequence creation courses, typically this shall be a dedicated course provided to test set users with the requisite skill set.

9.5 Specialist Training

Examples of dedicated training would be the power quality module, network simulation packages and advanced automated test template development training. It is certain there are several other examples. *Supplier* to detail or list the additional software modules with its associated training cost.

9.6 Trainee evaluation

All training courses shall include the evaluation of each student and declare the student competent; a certificate of attendance is issued, and student is declared competent. If a trainee is not competent, the trainee shall receive a certificate of attendance, but no declaration of competency is made. Students are expected to attend the full course, should this not be the case the attendance certificate should state “Partial attendance”. If the course provider however deems the person to still be competent the attendance certificate should state “declared competent”.

10. Support

Support shall be a key determining factor when doing tender evaluation. The following support items shall be a definite requirement:

a) Local repair and calibration with a turnaround time typically better than 14 days.

b) Formalised training courses as described. Training shall take place at or near the *Purchaser*‘s offices around the country, when sufficient student numbers justify this; or virtual training as required.

c) Technical support shall be available via email and telephonically or any other form of electronic communication by technical competent support staff who is within 2 hours of South African time zone. Technical competent would mean personnel with tertiary Electrical engineering qualifications and having hands on experience testing protection IED’s that are used in the Purchaser’s division (Transmission.)

d) Lastly the *Supplier* shall provide proof of the required support functions. This will be a list of technical staff and a short CV of each member, courses provided over the past years and to which companies. Physical examples of automated templates and the end customer.

11. Automated Test Templates

a) Capability and capacity to develop automated testing templates on request. This service shall be done on request from the *Purchaser* with a detailed scope of work supplied by the *Purchaser*. Typically, a test template will extract settings from the *Purchaser’s* setting sheet and make it available to the test set software by some software importing method. The template will detail all wiring requirements and setting and wiring alterations as the template testing progresses. The test template would on all schemes also involve IEC61850 based testing. The template shall run with the minimum of operator intervention and focus on all aspects of personnel and hardware safety. The test template shall generate a formal report with a detailed test report. This test template shall be verified, and field tested prior to handover to the Purchaser. On handover of the template, training to the *Purchaser* personnel is a requirement.

b) Compatibility with the Purchaser’s existing automated test templates is required. These templates have been developed to be utilised in conjunction with Omicron 256, 356. Alternatively, *Suppliers* can submit proposals to migrate existing automated test templates to a format that is compatible with their proposed products.

12. AB Schedule

There are three A&B Schedules pertaining to this enquiry viz. Protection MFT A&B Schedule; a Metering MFT A&B Schedule; Cyber Security and IEC 61850 Network Tools A&B Schedule. Each *Supplier* shall be issued with these schedules as part of the tender document package. A *Supplier* may tender for a Protection MFT; a Metering MFT; Cyber Security and IEC 6150 Network Tools or a combination of any of the above items.

It is important to complete the schedule accurately and provide references for each response detailing the section and document with page number, that the response can be verified. Where the *Supplier* cannot comply or meet the specific criteria this shall be stated as such.

13. Practical Demonstration

The tender evaluation will include a physical practical demonstration of the MFT and software by the *Supplier* to the *Purchaser* technical team on how to setup the software test module and physically testing the supplied product or products. The medium of communication will be English.

The demonstration shall be done by the local representative of the vendor; the local representative shall not be supported by an offshore specialist either at the preparation or demonstration stage. All *Suppliers* will be given the same product to test and the same time slot.

Each *Supplier* where possible will be given the opportunity to familiarise themselves with the product. The product will be located in a laboratory and be powered up with the requisite circuit breaker simulator if applicable. In addition, the setting sheet, the schematic and the IED software will be available on the day.

The *Supplier* will be responsible for any damage of the product. The *Purchaser* will only provide limited support.

A technical panel selected by the *Purchaser* will evaluate the demonstration which will form a substantial part of the technical compliance assessment.

14. Acceptance

This document has been seen and accepted by:

Name and surname	Designation
Dumi Nthongoa	Senior Manager - Grids
Anthea Solomon	Secondary Plant Manager (Apollo & Centralised Services)
Bosaletse Mpesi	Secondary Plant Manager (South Grid)
Ravi Govender	Secondary Plant Manager (East Grid)
Ellan Phaahla	Secondary Plant Manager (North Grid)
Gert Maphutsi	Secondary Plant Manager (Central Grid)
Humbulani Tshisevhe	Secondary Plant Manager (North East Grid)
Regi George	Secondary Plant Manager (West Grid)
Mbali Nyalunga	Maintenance Manager (Apollo Converter Station)
Andre De La Guerre	Middle Manager: PTM&C Protection, Metering and DC Technology & Support
Nelson Luthuli	Senior Manager (Acting): PTM&C
Anita Oommen	SCOT Protection and Automation Study Committee Chairperson

15. Revisions

Date	Rev	Compiler	Remarks
April 2022	1	K Jagdaw	This is a new document.

16. Development Team

The following people were involved in the development of this document:

- Jan Cronje
- Ferdi Hahn
- Gerald Valtein
- Eugene Du Preez
- Ian Worthington
- Patrick Mashigo
- Eugene Van Staden
- Gerhard Sommer
- Nicholas Baloyi
- Samuel Letwaba
- Kedumetse Masiangoako
- George Wolhuter
- Mohamed Omar

17. Acknowledgments

The development team of 240-102634558, which this document is based on.